LARIMER

Design of a Storage Reservoir for Irrigation

Civil Engineering

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DESIGN

OF A

STORAGE RESERVOIR FOR IRRIGATION

BY

ROBERT SHERMAN LARIMER

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

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COLLEGE OF ENGINEERING

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PRESENTED JUNE, 1907

C O L L E G E O F E N G I N E E R I N G

April 30, 1907.

This is to certify that the following thesis prepared under the immediate direction of Professor J. P. Brooks, Assistant Professor of Civil Engineering, by

ROBERT SHERMAN LARIMER

entitled DESIGN OF A STORAGE RESERVOIR FOR IRRIGATION

is accepted by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

Head of Department of Civil Engineering

UNIVERSITY OF ILLINOIS.

June 1, 1907.

This is to certify that the thesis prepared under the immediate direction of Professor J. P. Brooks by

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Head of the Department of Civil Engineering

CONTENTS.

DESIGN OF A STORAGE RESERVOIR FOR IRRIGATION.

Introduction.

Irrigation is one of the oldest arts, having been practiced in Egypt and parts of Asia for a long time previous to the Christian era, but its use, to any great extent, in America began at a very recent date.

As the agricultural regions of the United States became fully occupied, settlers began looking to the West for new lands. But, in their minds, the only use to which the semi-arid parts of our country could be put was cattle raising, and that only in a very crude way. There was no need to be economical with the land; there was plenty of it, unoccupied, and free to all users. But the advance of civilization, as it might be called, brought about a new state of affairs. It soon became apparent that to make a success of ventures in the West, it would be necessary to adopt some other methods of getting profit out of the land. It was too dry for crops to grow, although an abundance of water flowed through the beds of the streams in the spring. Some method had to be found of putting this water to use, and the results of the efforts of these settlers is shown in the system in use today for irrigation. There is plenty of water, but it is not available at the proper time for use in raising crops. Storage must be provided, so that this water may be stored until needed.

In the eastern part of the state of Colorado is one of the most productive regions in the United States, sugar beets being the principal crop raised. Some reservoirs are construct-

ed near the place where the water is to be used, but others are built in the mountains at a considerable distance from the land to be irrigated. There it is often possible to find a location where a comparatively small dam, placed in a narrow canon, will cause the formation of a large lake. The reservoir described in the following pages is of the latter variety, and while not extensive, a comparatively large storage capacity is afforded by a small dam. A very much larger storage capacity could be obtained by an increase of a few feet in the height of the dam, but this would necessitate the construction of several low dams, not exceeding about fifteen feet in height, and for the purpose of this paper it was thought superfluous to consider this condition. However, when the reservoir is built, this point will probably be taken advantage of, on account of its commercial value.

Location.

The Forest Canon Reservoir is located in Larimer County, Colorado, and is also within the boundaries of the Medicine Bow Forest Reserve. The dam is within a few miles of the headwaters of the Big Thompson Creek, in what is known locally as Forest Canon. At the dam-site the creek flows through a narrow gorge where the slope of the stream is very great. It would be possiblo, by going down stream a short distance, to find a narrower site, but on account of the high gradient of the stream, to raise the water to the same level would necessitate a dam of considerably greater height. The choice of the site was made after a very careful examination of the existing conditions; and it was decided that it was in expedient to go far-

ther down stream for the location of the dam.

One of the serious disadvantages under which construction must be carried on, is the inaccessibility of the location. By the most direct route, it is now necessary to haul material by wagon a distance of about thirty miles, and over about four miles of trail. A road can be built to the site, but only at a very great expense, owing to the extreme roughness of the country through which it must pass. If possible,work would be carried on by building the road over only about half of this trail, over which the construction would be comparatively easy..

There is on the site to be covered with water, plenty of timber, mostly red spruce, and an abundance of rock of granitic structure, granite gneiss being the predominating variety. The presence of these two materials was the factor in determining the type of dam to be used. In connection with the construction of the dam and flumes, a large quantity of sawed lumber will be necessary and as water power is available with a slight expenditure, a portable saw-mill will be used to cut all of the lumber required.

Laws relating to Water Rights.

Colorado was one of the first states to make laws governing the storage and use of water for irrigation purposes, and it has today a very complete code on this subject. To obtain the right to store water for irrigation and to construct ditches for carrying water, it is necessary to comply with these requirements and regulations. Where the site for a reservoir is on public land, in this case a forest reserve, a permit is required from the federal government. The laws of the State of

Colorado will be taken up first.

In compliance with Chapter 126 of the Session Laws of 1903, and the regulations of the State Engineer's office thereunder:- "Every person, association, or corporation hereafter constructing or enlarging any reservoir or reservoirs, constructing, changing the location of, or enlarging any ditch, canal, or feeder for any ditch or reservoir, for the purpose of furnishing a supply of water for domestic, irrigation, power or storage, or any other beneficial use, taking water from any natural stream, shall, within sixty days after the commencement of such construction, change of location, or enlargement, make filings in the office of the State Engineer for each specific claim. * * * " - Sec.1, Chap.126, S.L. 1903. The filings referred to consist of maps made in duplicate. The duplicate is examined and certified to by the State Engineer, so that it may be returned and filed in the office of the county clerk within ninety days of the commencement of construction.

Maps must be on a good quality of tracing linen, 24 by 36 inches, with a two-inch margin on the left hand side, making the available space for the map 24 by 34 inches. All maps must be made this size irrespective of the size of the reservoir or ditch to be shown, and not folded.

The scale of the map must correspondingly vary, but should be sufficient to show clearly each course and distance. It is desirable in the case of reservoirs, that the scale should be four hundred feet to the inch or larger when needed to show the proposed works, if practical. In case the sheet is not of sufficient size for this purpose, then the map must consist of

two or more sheets. In such a case each sheet should be marked "Sheet No.1", "Sheet No.2", etc., and each sheet properly titled.

The ink used in making these maps must be water-proof for permanent record, and either Higgin's (water-proof) or Windsor and Newton's Liquid India ink may be used for this purpose. It is also desirable to have the signatures and dates put on with water-proof ink, if possible.

All statements are placed on the same sheet or sheets as the map.

The title must include the following; Name of reservoir; Location, by county, irrigation division and water district; Magnetic variation; and Scale.

The form of statement is as follows; "Know all men by these presents: That the undersigned .....,claimant.., whose postoffice address is ....., has caused to be located The ..... Reservoir as hereinafter mentioned, have made those several statements relative thereto, and filed in compliance with the law of the State of Colorado. The accompanying map, which shows the location of said reservoir, forms a part of this filing and is hereby made a part thereof.

First. Height of dam,....feet.

Second. The following table gives the areas and capacities for each foot in depth from the bottom of the outlet tube up to and including the high-water line:

Depth in feet.	Area in sq.ft.	Capacity in cu.ft.
Bottom of outlet tube ..0 ft.	.....	.....
1 ft.	.....	.....
2 ft.	.....	.....
Highwater line..ft	.....	.....

Total capacity of said reservoir is .....feet of water for which claim is hereby made for .....purposes.

Fourth. The source of supply of said reservoir is from .....

Fifth. The estimated cost is $.....

Sixth. Work was commenced by ..... on the ....A.D.190...

The map of the reservoir should show the following;

First. The location of the initial point of the survey by course and distance to a corner of the public land survey, or to some natural object if on unsurveyed land.

Second. The high-water line of the reservoir by course and distance, the location of the dam and approximate contours at five foot intervals.

Third. The stream and name thereof upon which the reservoir is located should be shown on the map.

Fourth. Ditches to and from reservoir, name, course and distance, with grade, section of water prism and capacity in cubic feet.

Fifth. Legal 40-acre subdivisions and other patented lands.

Sixth. Ownership of the land on which the reservoir is located, or through which the inlet or outlet ditches pass.

An affidavit must be made out by the claimants in the following form:

" State of Colorado,)
County of .....,) ss.

.....etc.,claimants, being duly sworn on oath, depose and say that having read and examined the map and statements hereon, that the same are true to the best of our knowledge and belief.

.....,

....., etc.

Subscribed and sworn to me this ....day of....A.D.190..

My commission expires.....

.....,

Notary Public.

The engineer must make affidavit as follows:

" State of Colorado,)
County of.....,) ss.

.....,being duly sworn on his oath, deposes and says that he is the engineer of the .....Reservoir, and that the survey of the same and the map was made by him (or under his instructions) and that such survey is accurately represented upon this map; and that he has read the statements thereon, and that the same are true to his own knowledge.

.....,

Engineer. (or Surveyor.)

Subscribed and sworn to this ....day of ....A.D.190..

My commission expires .....

.....,

Notary Public.

The following affidavit is placed upon the map that is filed in the office of the State Engineer:

State Engineer's Office.
Denver, Colorado.

" State of Colorado,)
City and County of Denver,) ss.

I hereby certify that this map and statement has been examined and approved by me as agreeing with the statutes of the State of Colorado and the regulations of this office, and was accepted for filing on the ....day of .....A.D.190...

.....,

State Engineer.

By.....,

Deputy.

The following is the form of affidavit to be placed on the duplicate or the map to be filed in the office of the county clerk after being signed by the State Engineer;

State Engineer's Office.
Denver, Colorado.

" State of Colorado,)
City and County of Denver,) ss.

I hereby certify that this map and statement has been examined and approved by me, and is a duplicate of the one filed in the office of the State Engineer on the .....day of .....A.D.190...

.....,

State Engineer.

By.....,

Deputy.

The filing fee is one dollar for each claim and one dollar for certifying to the duplicate copy.

The law of 1901 providing for headgates, rating flumes, surveys of reservoirs, etc., enacted by the General Assembly of tho State of Colorado, is as follows;

"Section 2. Whenever any owner or owners of any irrigation ditch,canal, flume or reservoir in this state, taking water from any stream shall fail to erect or maintain in good repair at the point of intake of such ditch, flume, canal or reservoir, a suitable and proper headgate, and measuring flume or weir, together with the necessary embankments therefor, of sufficient height and strength to control the water at all ordinary stages, with a framework constructed of timber not less than four inches square, at the bottom, sides and gate or gates of plank not less than two inches thick, then the State Engineer or Superintendent of Irrigation shall, upon ten days' previous notice in writing duly served upon the owner or owners of such irrigation ditch, canal, flume or reservoir, or upon any agent or employe representing or controlling the same, refuse to deliver to such owner or owners of such irrigation ditch, canal, flume or reservoir, any water from such stream until such owner or owners shall be caused to be erected or repaired the headgate, headgates or measuring flume of such ditch, canal, flume or

or reservoir.

"Section 2. Whenever the owner or owners of any irrigation ditch, canal, or reservoir transferring water from one public stream to another, or from a reservoir, ditch, or flume to a stream in order that the same may be diverted therefrom for irrigation or any other purposes, shall fail and neglect to construct suitable and proper measuring flumes or weirs for the proper and accurate determination of the amount and volume of water turned into, carried through and diverted out of said public stream, then the State Engineer or the Superintendent of Irrigation shall, upon five days' previous notice in writing duly served upon the owner or owners of any such irrigation ditch, canal, or reservoir, or agent or employe thereof, so transferring water from one public stream to another, or from any ditch, canal, or reservoir to a public stream for conveyance therethrough, refuse to allow to be taken and diverted therefrom, any water whatever on account of delivery of water thereto, for such time and until such owner or owners shall cause to be erected or repaired such flumes or weirs at the point of delivery to and taking from said public stream so used as a conduit.

"Section 3. The State Engineer or Superintendent of Irrigation shall rate the measuring flumes and weirs referred to in sections one and two of this act, and shall supply the superintendent of the division and the water commissioner of the district in which such measuring flumes or weirs are located, with a rating table, which shall be used by them in measuring

water flowing to and from such public stream.

"Section 4. The owners or possessors of reservoirs shall not have the right to impound any water whatever in such reservoir during the time that such water is required in ditches for direct irrigation or for reservoirs holding senior rights. A gage rod shall shall be permanently fixed and maintained at the outlets of said reservoirs, and if any owner or possessor of any reservoir shall fail or refuse within thirty days after this act goes into effect, to provide, fix and maintain such gage rod or rods, as aforesaid, then and in that event the owner orpossessor of such reservoir shall not be entitled to impound any water whatever in such reservoir or reservoir until the provisions of this section are fully complied with.

"Section.5. All headgates and measuring weirs used in connection with canals, flumes, ditches and reservoirs for the measuring and delivery of water therefrom and thereto, shall be under the control and supervision at all times of the State Engineer, the Superintendent of Irrigation of the water division and the water commissioner of the water district wherein such headgates and measuring weirs are located.

"Section 6. The owner or owners of any reservoir situate upon or in the bed of any natural stream or through which any natural stream runs, for the purpose of storing water to be diverted at a point further down said stream, shall,at the expense of the owner or owners, cause a complete survey of the contour lines of said reservoir to be made by the State Engineer, and it shall be the duty of the State Engineer to make such survey upon the request of the owner, which said contour

lines shall be ascertained for at least every vertical foot in depth, and, in all cases where deemed necessary by the State Engineer, for fractions of a foot; and a table to be prepared showing the number of cubic feet capacity of said reservoir for each foot in depth and fraction thereof; and a gage rod placed in said reservoir, marked in correspondence with said contour lines, from which tho amount of water stored in, or taken from, said reservoir, may be ascertained. And in case of failure so to do, the said State Engineer or Superitendent of Irrigation shall refuse to be allowed to be taken into, or diverted from, said reservoir, any water whatever; Provided, however, That in all cases where for any reason said State Engineer may find it impracticable to make said survey, the owner or owners of said reservoir may continue to store and deliver water upon providing a suitable and proper measuring flume or weir for the accurate ascertainment of the amount of water discharged from said reservoir.

"Section 7. All acts and parts of acts inconsistent herewith are hereby repealed. "

As was stated previously, the permission of the federal government is required to construct reservoirs on public lands. If the reservoir is to be used for storing water for generating power, a permit is obtained from the Forest Service, which is under the control of the Department of Agriculture. If the reservoir is a part of an irrigation system, the right of way may be obtained from the Forest Service or from the Department of the Interior. To obtain the permit from the first mentioned department, application must be made on a form furnished by

the Forest Service, and to be filed with the proper Forest Supervisor. The mannor of filing the application with the Department of the Interior is similar, the proper form being furnished by the Land Office.

The Survey.

The method of obtaining the data for the required map and for designing the dam, was one which differs from the usual method in several respects. In the first place, great accuracy was not required and, on account of the extreme roughness of the country covered, could not be maintained except with great care.

All level and transit work was done with a Heller and Brightly mountain transit with vertical circle and attached bubble tube. The length of the telescope is about eight inches and of the needle about three and one-half inches. The horizontal circle is four and three-quarter inches in diameter, graduated to half-degrees with two verniers reading to minutes.

The survey was tied to a point on a knob of rock indicated by a cairn of loose rocks. A bench mark was established near this point and the elevation assumed as thirty feet, being the elevation above the stream at that point. A line of levels was run up stream from this point and another bench mark located at the same elevation. The length of this line showed that a very small area would be flooded by constructing a thirty-foot dam and an increased height of dam would be necessary to make a reservoir of sufficient size to warrant the undertaking. Upon examination it was found that the highest dam that could be built

on the site chosen would be forty feet; that is, if the water were raised more than this distance, it would flow out through a low cut near the dam-site. Accordingly the high-water contour was commenced on the forty-foot level. The instrument was set up over the initial point whose elevation was known, and a sight taken ahead to a point where the target set at the height of the instrument came on the level line. The azimuth of the line to the rod was measured from magnetic north as determined from several careful readings of the needle. The distance was measured by reading the stadia wires on the rod. A turning point was set between the stations, and the instrument brought up. A back sight was taken to set the plates, and a level sight taken to the rod held on the turning point. A sight was taken ahead again, locating another point on the high-water contour, and another turning point was set. Proceeding in this manner,the line was carried to a point where it crossed the stream, where another bench mark was set, about four feet above the high-water line. The line was then carried back along the other side of the stream in a similar manner to within a short distance of the dam-site where a steep, rocky slope was encountered. It was found to be very difficult to proceed on the high-water contour, so the line was carried to the foot of the slope and continued to the dam-site. The line was closed back on the initial course and, while there was considerable error, it did not exceed what was considered allowable in this kind of work. On account of the line being at the foot of the slope, and therefore below the first bench mark, the closing

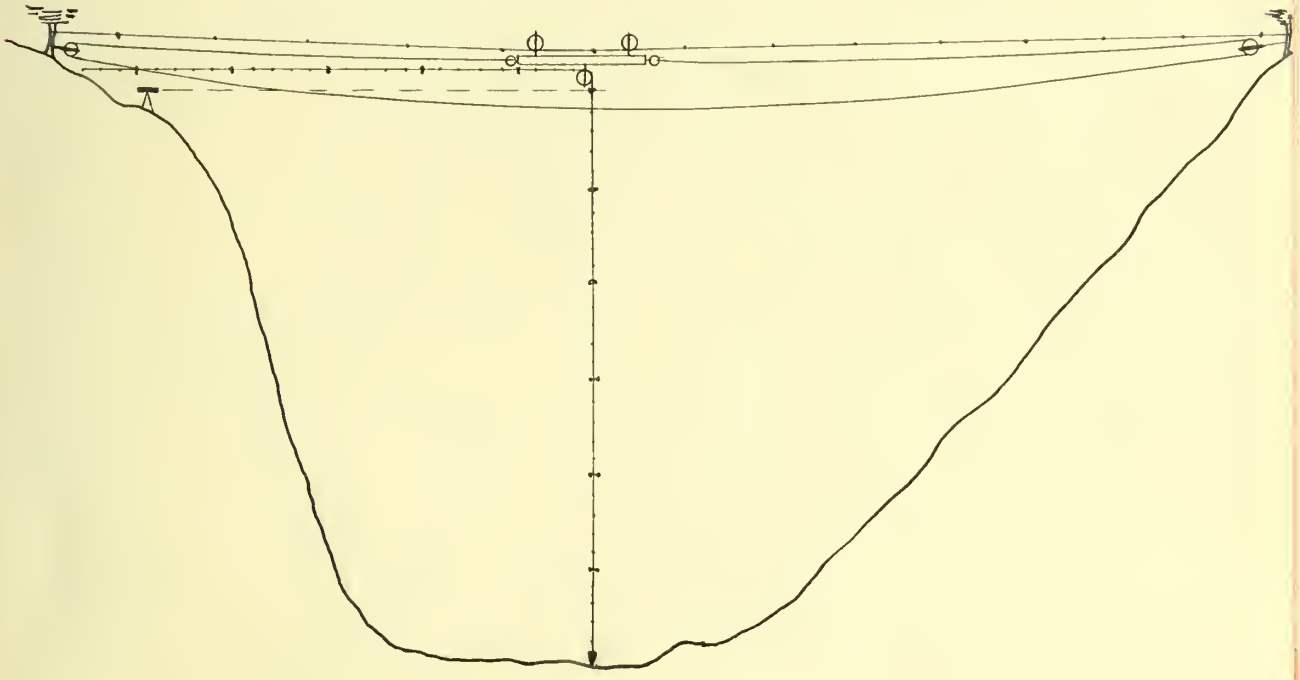
line was read on the vertical circle and the difference of elevation computed. The levels checked close enough for the work.

To obtain the topography in the area enclosed by the high-water line, side shots were taken from the stations on the traverse to controlling point on the ground surface. Two secondary traverse lines were also run from one end of the area to the other, tying to the initial point, and shots taken from these to locate the controlling points.

The method used in obtaining the profile of the dam-site was used on account of several peculiar conditions and difficulties that presented themselves. On one side the rock rises perpendicularly from the water and on the other side the slope is very steep. The instrument could be set up only at the top and bottom of the site. It was concluded that an over-head traveller should be rigged up to carry a plumb-bob attached to a graduated cord. By means of graduations on the line carrying carrying the traveller, the position of the plumb-bob was found, having first tied the terminals of the traveller line to the initial point of the survey. The graduations of the plumb-line were read with the instrument set level at the top of the slope.

The traveller line was streched across the stream in parallel positions, as shown by the diagram below. The course and distance of the line from Station 1 to the point A_1 was found and the course of the line A_1-A_2. Having laid off equal distances along the line A_1-D_1, equal distances were measured out on

the lines A_1-A_2, B_1-B_2, etc., and the result is a rectangular system from which the measurment can be easily taken. The plumb line was read at the intersection of the lines shown in the diagram. This furnished very convenient data for plotting.



Apparatus Used for Profiling Dam-site.

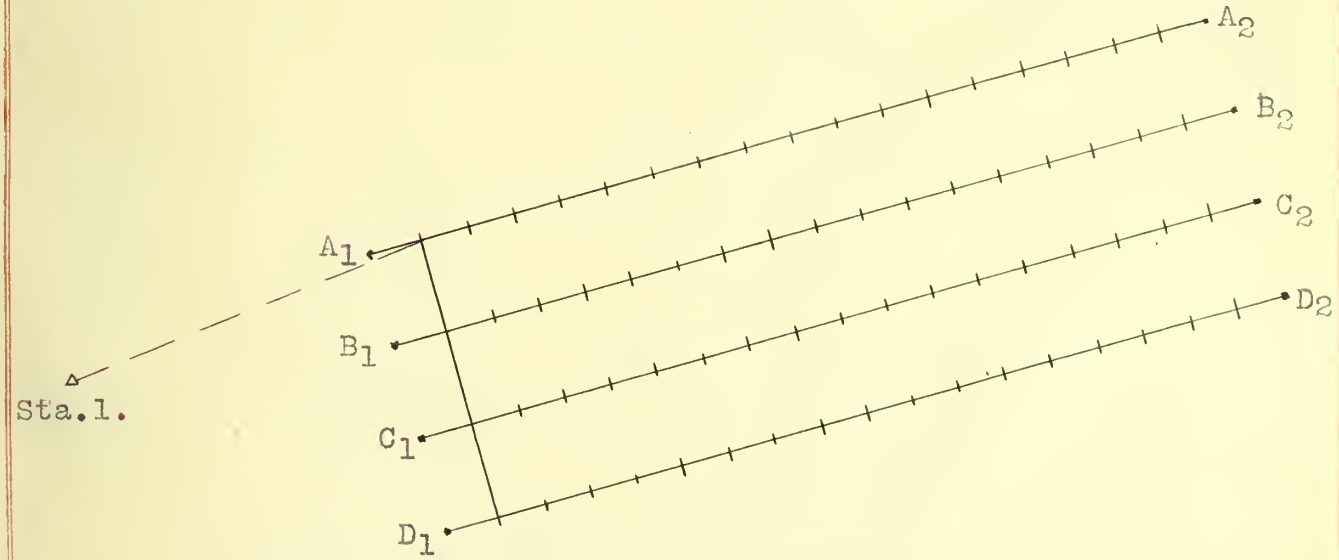


Diagram Showing Position of Traveller Lines.

The errors in this survey do not come within the limits allowed for ordinary work but as this is only intended to furnish data for filing, and also on account of the roughness of the territory covered, greater accuracy in the work would not be warranted. Construction surveys would be necessary for the dam site and waste-channel work, but sufficient data have been obtained for an estimate of the work required.

Computation of Discharge.

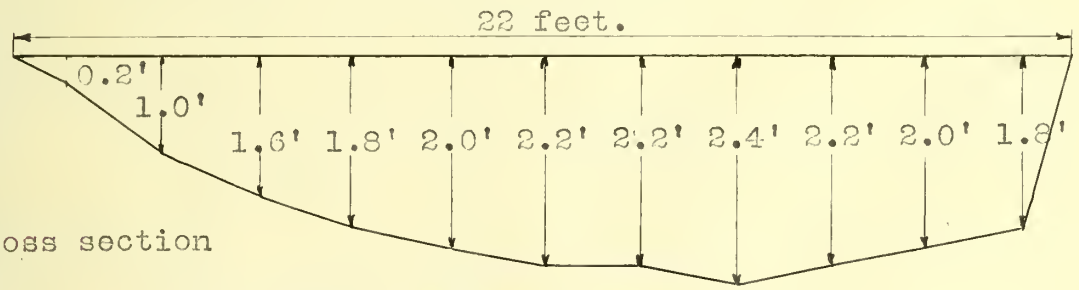
It was necessary to know the discharge of the stream flowing into the reservoir. The nearest gaging station is at a considerable distance from the site and the data obtained there is valuable only as a means of estimating the discharge of the stream at the site of the proposed dam. On account of the short time during which the stream could be gaged, it was impossible to obtain data for a long enough time to be of much value. One careful gaging was made, and having the discharge curves of several other streams draining similar catchment basins in the same locality, an estimated curve was plotted. This was done by comparing the discharge obtained at the dam-site with the mean of the discharges obtained on the same date on the other streams. Of course this method furnishes only an approximate curve, but one which will fulfill the purpose for which it is intended.

The method employed in gaging the stream will be described. The Big Thompson Creek flows through a comparatively rough country in the vicinity of the proposed reservoir. The only method that was practicable was that of measuring the velocity and mean cross section area in a straight channel. The longest

stretch available was fifty feet long, and as it was of very uniform cross section, the sectional area at the middle point only was found. A tape was stretched across the stream and the depth read at two foot intervals along the tape with a graduated rod. A summation was made of the trapezoids thus formed, and the result was taken as the mean cross section of the channel.

In obtaining the velocity of the stream, the lack of a current meter made it necessary to use floats. A number of surface floats were used, which were placed at different points across the stream. The time taken to traverse a measured distance was noted, and the mean of these times divided into the length of the course gave the mean surface velocity. The ratio of the surface velocity to the mean velocity of the stream was found in Merriman's "Treatise on Hydraulics", and multiplying by this coefficient, the mean velocity of the stream was obtained. Combining the two factors, the discharge of the stream was found.

The following is the data obtained:



Cross section

Area = a = 36.7 square feet.

Time of float = 16.57 seconds. Length of course = 50.00 feet.

Mean surface velocity = $\frac{50.00}{16.57}$ = 3.01 feet per second.

Mean velocity coefficient = 0.8 (Merriman's, page 316.)

Mean velocity = 3.01 x 0.8 = 2.41 feet per second. = v.

Discharge = q = Area x Velocity = a x v

Discharge = 36.7 x 2.41 = 88.3 cubic feet per second.

Rainfall and Runoff.

In connection with all projects dealing with water supply, the amount of runoff from the drainage area should be known. Knowing the several factors, formulae may be used to determine the runoff. In this case, however, data obtained and furnished by the Hydrographic Division of the United States Geological Survey have been used, thus making extended computations unnecessary. In "Water Resources of the State of Colorado", (Water Supply and Irrigation Paper No.74) are found data obtained on the Big Thompson Creek, and also on several other streams draining similar catchment basins. The mean runoff is given both in second-feet per square mile and inches. Having found the area of the catchment basin, the total runoff is obtained.

In designing waste weirs, it is necessary to know the greatest flood flow that will occur at that point. This is a very uncertain quantity and can only be determined by the records of floods for many years. It is necessary to have the waste weir large enough so that no water will ever flow over the crest of the dam, and as the maximum flood will nearly always occur when the reservoir is full, there must be a large margin of safety in the capacity of the waste weirs. From the table of rainfall, the maximum precipitation in twenty-four hours was assumed and allowing for a certain percentage of this flowing off with the flood, the maximum runoff was obtained.

Below are the computations of the runoff:

Area of drainage basin = 18.0 square miles.

Inches of rainfall for storm of maximum duration = 3.0 inches.

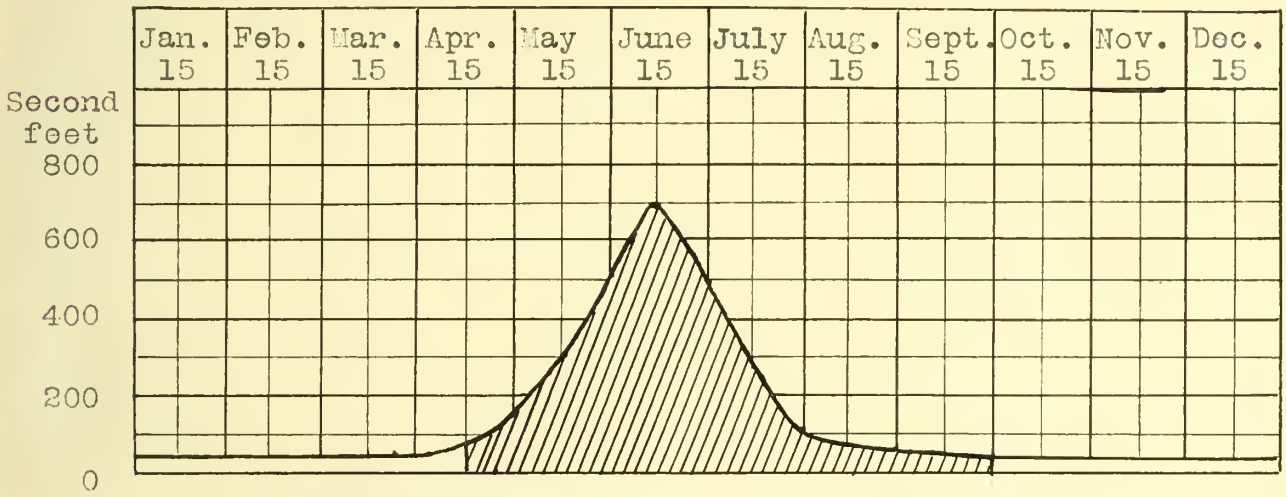
Amount running off = 50 per cent.

Inches of runoff in flood = 0.50 x 3.00 = 1.50 inches

= 0.12 feet.

Runoff per square mile = $\frac{43560 \times 640 \times 0.12}{60 \times 60 \times 24}$ = 38.7 cubic feet.

Total runoff = 18.0 x 38.7 = 695 cubic feet per second.



Normal Estimated Discharge of Big Thompson Creek.

Capacity of Reservoir.

Having made the survey of the reservoir site and plotted the results, it remained to compute the capacity of the reservoir. The five-foot contours furnish the necessary data for this. By means of a planimeter, the area enclosed by each contour was found and applying the prismoidal formula, the capacity was computed, as shown below.

$$\text{Volume} = \frac{5 \times 2}{6}(A_1 + 4A_2 + 2A_3 + 4A_4 + \cdots + A_n)$$

From Raymond's "Plane Surveying" page 283.

(For values of A_1, A_2, A_3, etc., see table following.)

$$\text{Volume} = \frac{10}{6}\ (\ 0 + 4 \times 15{,}053 + 2 \times 71{,}777 + 4 \times 121{,}100 + 2 \times 242{,}470 + 4 \times 426{,}000 + 2 \times 554{,}450 + 4 \times 746{,}200 + 1{,}055{,}563\ ) = 13{,}377{,}148 \text{ cu.feet}$$

$$\frac{13{,}377{,}148}{43{,}560} = 307.09 \text{ acre-feet} = \text{capacity of reservoir.}$$

Table of Areas and Capacities.

Depth in Feet		Area in Square Feet		Capacity in Cubic Feet
Bottom of Outlet Tube-	0	000	$= A_1$	000
	1	3006		2198
	2	6013		4396
	3	9019		65954
	4	12026		87939
	5	15033	$= A_2$	109924
	6	26381		131908
	7	37730		153893
	8	49079		175878
	9	60428		197863
	10	71777	$= A_3$	218848
	11	81641		352955
	12	91606		486063
	13	101370		619171
	14	111255		752279
	15	121100	$= A_4$	855357
	16	145374		1018494
	17	169648		1151602
	18	193922		1284710
	19	218196		1417818

Depth in Feet	Area in Square Feet		Capacity in Cubic Feet
20	242470	= A_5	1550926
21	279176		1967746
22	315882		2384566
23	352588		2801386
24	389294		3218206
25	426000	= A_6	3635026
26	451690		4051846
27	477380		4468666
28	503070		5302306
29	528760		5719126
30	554450	= A_7	6106938
31	592800		6484629
32	631150		7250730
33	669500		8016532
34	707850		8782334
35	746200	= A_8	9548137
36	808073		10313939
37	869946		11079741
38	931819		11845543
39	993692		12611345
High-water Line - 40	1055563	= A_9	13377148

(These areas were obtained from the map on Plate 1.)

Specifications.

Dam. (Plate 3.)

Description.

The dam is to be a timber crib, filled with rock, and approximately on the lines shown in the accompanying plans.

Foundation.

The foundation work for the dam shall be carried to such a depth and in such a manner as shall be ordered by the engineer in charge.

Timber.

All timber shall be spruce, as cut in clearing the reservoir site, and must be clear of all defects that may impair its strength or durability. With the exception of the cribbing, sawed lumber shall be used. All timber to be cut and fitted according to the accompanying plans. (Plate 3.)

Rock.

All the rock is to be obtained from within the area of the high-water line. The rock shall be roughly laid by hand, filling the voids with small pieces.

Outlet.

The valves shall be of the sluice gate type, operated by hand wheels placed on the top of the dam.

The pipe used for the outlet shall be of riveted steel, with an inside diameter of sixteen (16) inches and a thickness of metal of one-fourth (1/4) inch. All pipe to be furnished in lengths of not over six (6) feet, with the ends fitted with cast iron flanges drilled for bolts. The pipe shall be coated inside and outside with three (3)

coats of water-proofing material.

Waste-way. (Plate 4.)

Description.

The waste-way of the reservoir shall consist of a channel cut through rock at the position shown on the accompanying map. (Plate 2.) A flume must be provided for measuring the discharge.

Flume.

The flume shall be of timber, constructed according to the accompanying plans. (Plate 4.)

Inlet.

Description.

The inlet to the reservoir is through the natural bed of the stream, as shown on the accompanying map. (Plate 1.)

Flume.

The flume shall be of timber, constructed according to the accompanying plans. (Plate 4.)

Estimate of Cost.

Survey. (Field and office work, time and material.)

Field work, 18 days @ $15.00 per party,	$270.00	
Office work, 30 days @ $3.00	90.00	
Material,	10.00	
		$370.00
Construction of temporary roadways.		
Labor, 120 days @ $2.00		240.00
Clearing site.		
Reservoir, 24 acres @ $60.00 per acre	1440.00	

Clearing site (cont't)		
Dam-site, 40 days @ $2.00	80.00	
		1520.00
Sheds and barns.		
Material and labor,		150.00
Tools and Plant.		
(Derricks, carts, skips, tools, etc.,)		1000.00
Delivering and installing plant.		
Hauling and labor,		300.00
Interest and depreciation on plant.		
15 % of first cost,		150.00
Materials,		
Timber, (obtained from site free.)		
Rock, (obtained from site free.)		
Drift bolts, 5000 pounds, @ 3 cents,	150.00	
Valves, 2 @ $50.00	100.00	
Pipe, 3000 pounds @ 3 cents,	90.00	
Spikes, 2000 pounds @ 4 cents,	80.00	
Miscellaneous materials,	150.00	
		570.00
Freight.		
15 tons @ $4.00		60.00
Hauling.		
15 tons, 40 miles, @ 40 cents per ton-mile,		240.00
Labor.		
Handling rock, 1600 cubic yards, @ 30 cents,	480.00	
Handling and shaping timber, 100,000 feet board measure @ $1.00 per thousand feet,	100.00	
Sawing lumber, 50,000 feet, @ $4.00 per "M "	200.00	

Labor (cont'd)		
Excavation, 1000 cubic yards @ $1.00	1000.00	
		1780.00
Housing and boarding men.		
25 men, 10 weeks @ $3.50		875.00
Superintendence.		
70 days @ $8.00		560.00
Office expenses.		
Supplies and clerical force,		200.00
Total - - - - - - - - -		7915.00
Contingencies.		
10 % of total,		791.50
Profit.		
15 % of total,		1187.25
Grand Total - - - - - - - -		$9893.75

Cost per acre-foot stored,	$3.22
Cost per acre irrigated (duty of water assumed as 2 acre-feet per acre.)	$6.44

Conclusion.

The cost of this project shows the comparison with average conditions in Colorado, as given in Wilson's "Manual of Irrigation Engineering". From experiments made in Colorado, an application of water to the depth of about eighteen inches, distributed throughout the season, will raise good crops. This is equivalent to one and one-half acre-feet of water per acre of land irrigated. Allowing for losses due to seepage and evapor-

ation, which may amount to about thirty-three and one-third per cent, two acre-feet of water are required to irrigate properly, one acre of land. With an available capacity of three hundred and seven acre-feet ,it would be possible to irrigate one hundred and fifty-three acres of land. Dividing the cost of the project by this value, gives $6.44 as the first cost of water per acre. In Colorado, the average first cost of water is given as $7.15

As has been previously stated, an increase of fifteen feet in the height of the dam would increase the capacity of the reservoir to about eight hundred acre-feet. The cost of this project, it is estimated, would be $14,000.00 Allowing the same duty of the water as in the first case, the first cost of water per acre would be $3.25, a value considerably below the average for the state.

It is evident from the foregoing data that the construction of the reservoir as projected would be of commercial value.

In Colorado tracts of land still remain unoccupied for the lack of water, and with as good a proposition as the Forest Canon Reservoir appears to be, there is little doubt but that construction will be undertaken within a short time.

PLATE 1.

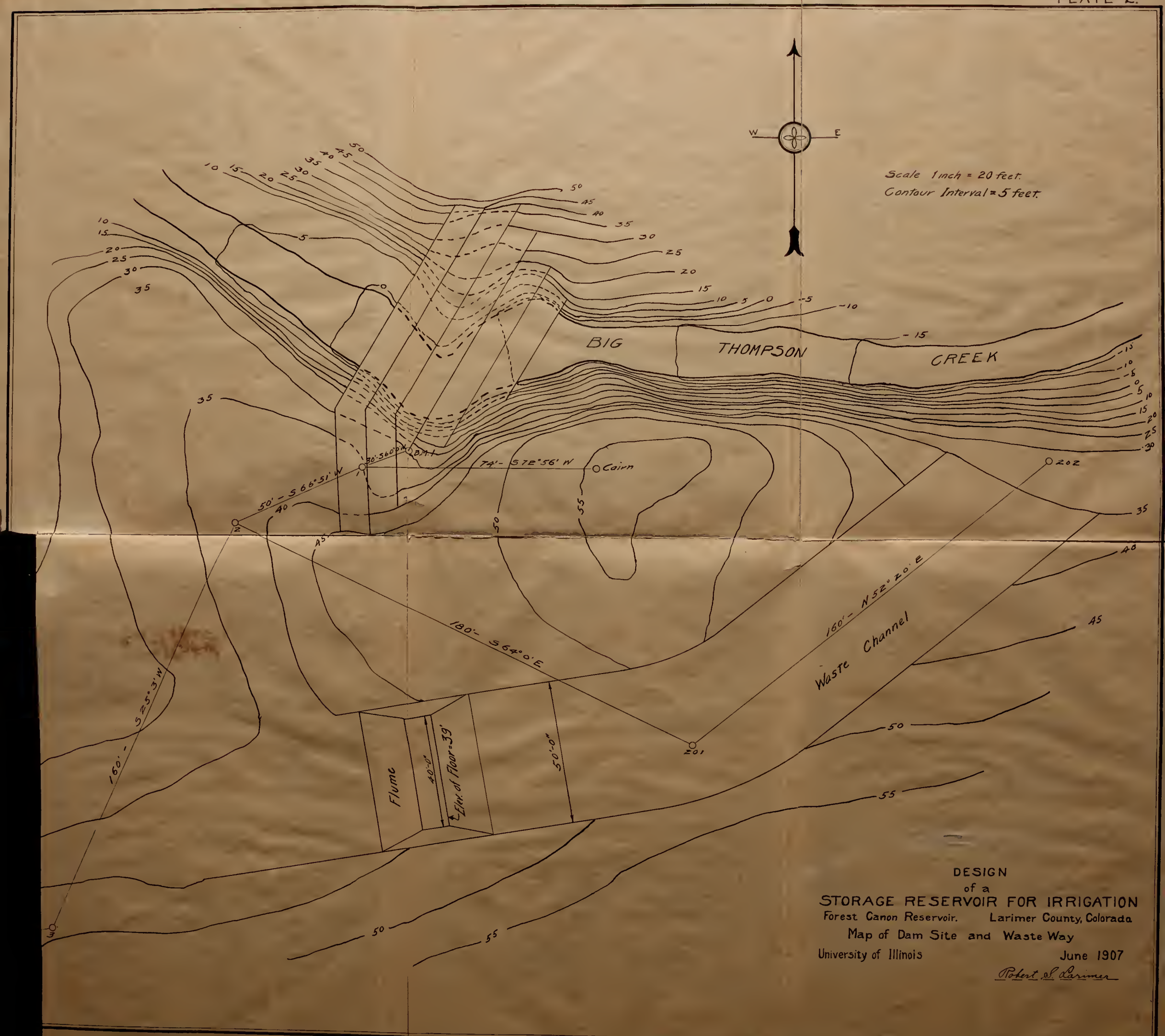
DESIGN
of a
STORAGE RESERVOIR FOR IRRIGATION
Forest Canon Reservoir, Larimer County, Colorado.
Map of Reservoir Site and Location.

University of Illinois

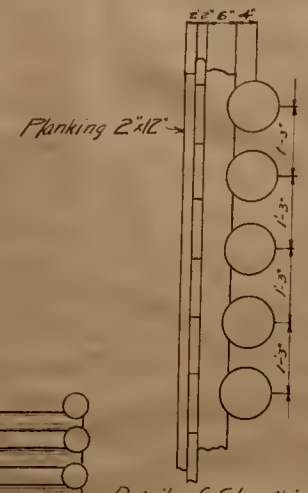
June 1907

Robert S. Larimer

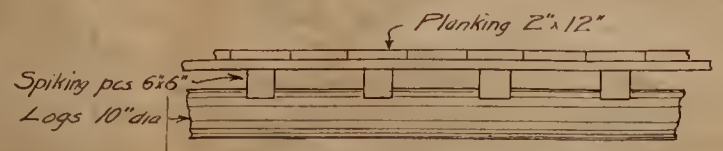
PLATE 2.



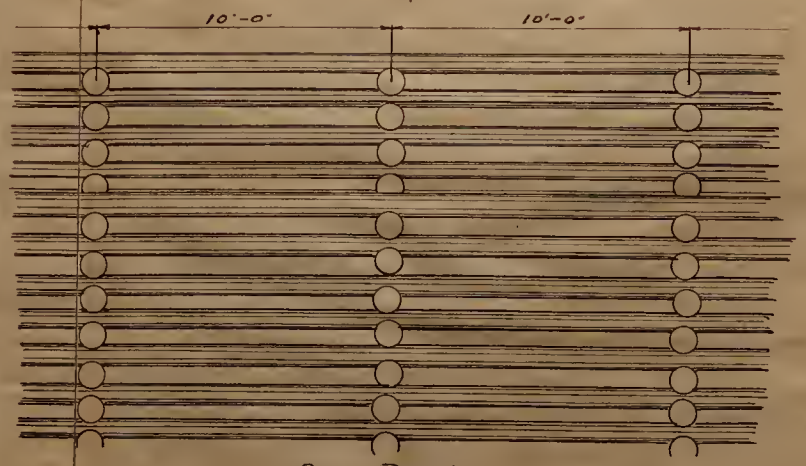
DESIGN
of a
STORAGE RESERVOIR FOR IRRIGATION
Forest Canon Reservoir. Larimer County, Colorado.
Map of Dam Site and Waste Way
University of Illinois June 1907
Robert S. Larimer



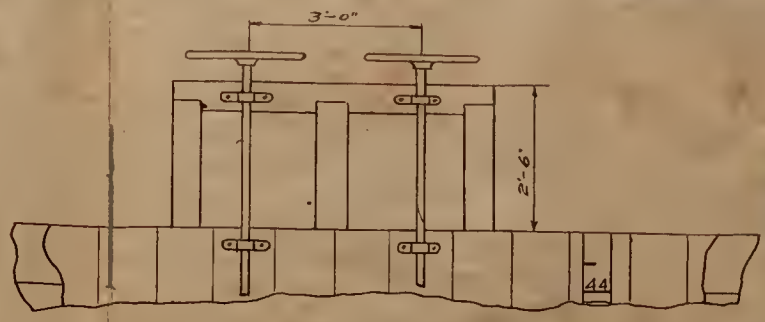
Details of Sheathing

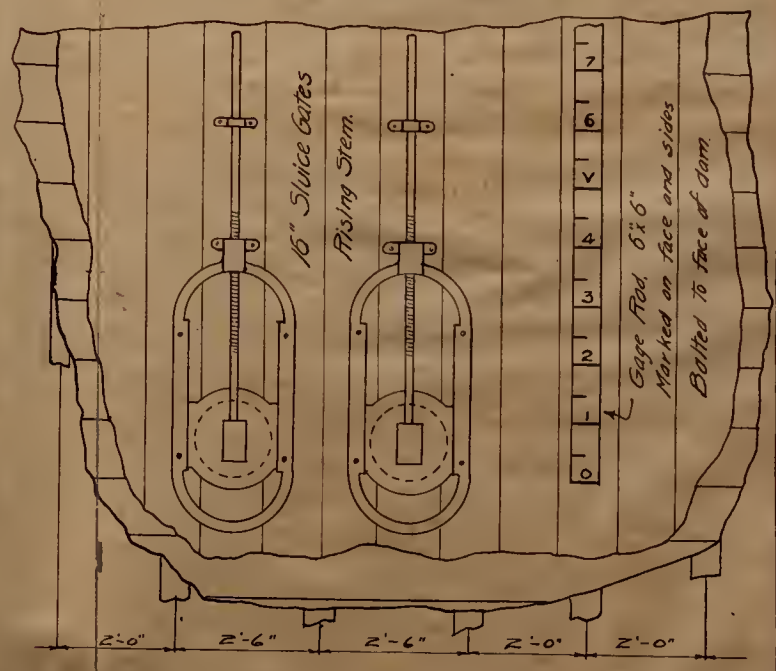


Details of Sheathing.



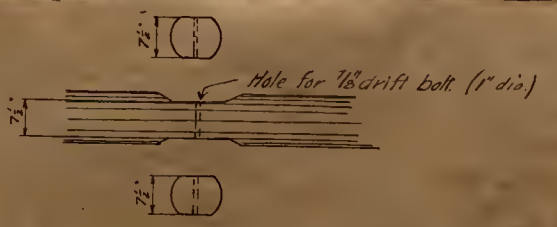
Dam - Rear View.





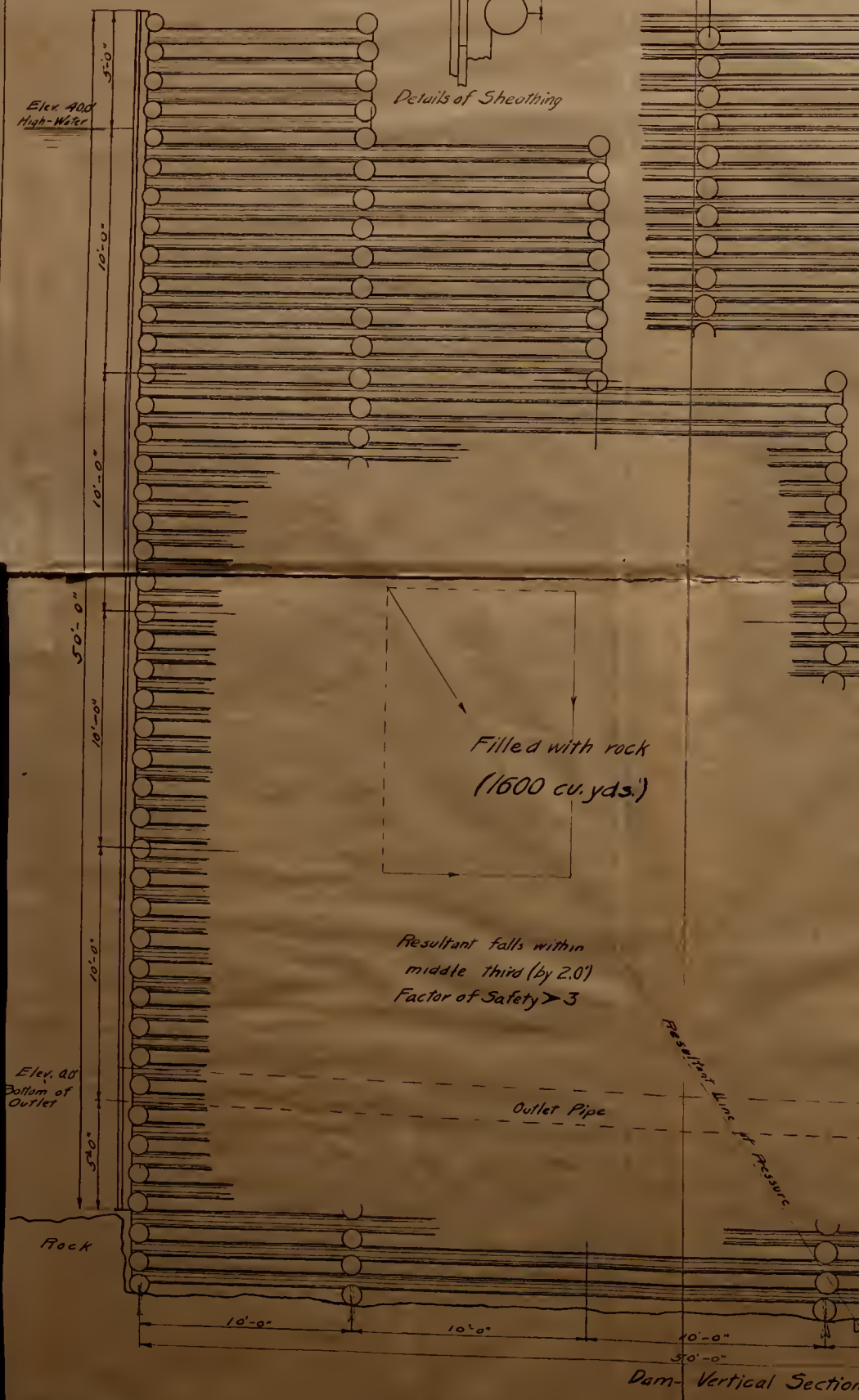
Face of Dam - Valves & Gage

Scale, 1 inch = 2 feet



Details of Joint

Scale, 1 inch = 4 feet



Dam - Vertical Section

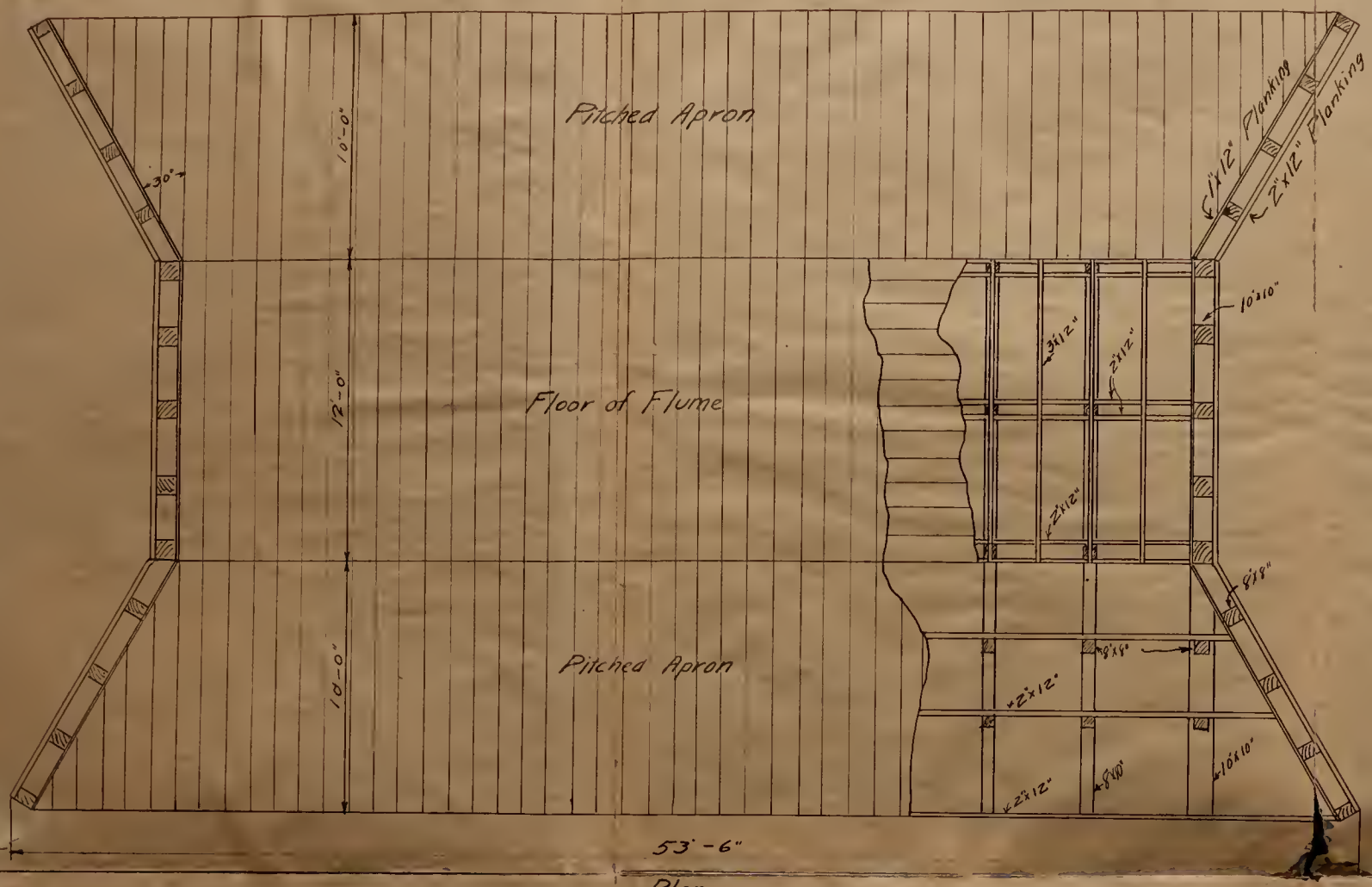
DESIGN
of a
STORAGE RESERVOIR FOR IRRIGATION
Forest Canon Reservoir Larimer County, Colorado.

Details of Dam

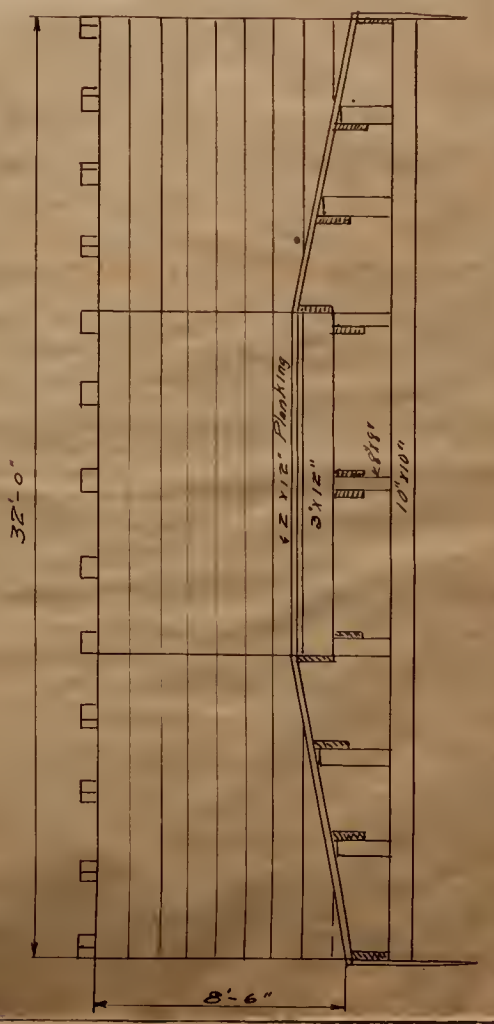
University of Illinois

June 1907

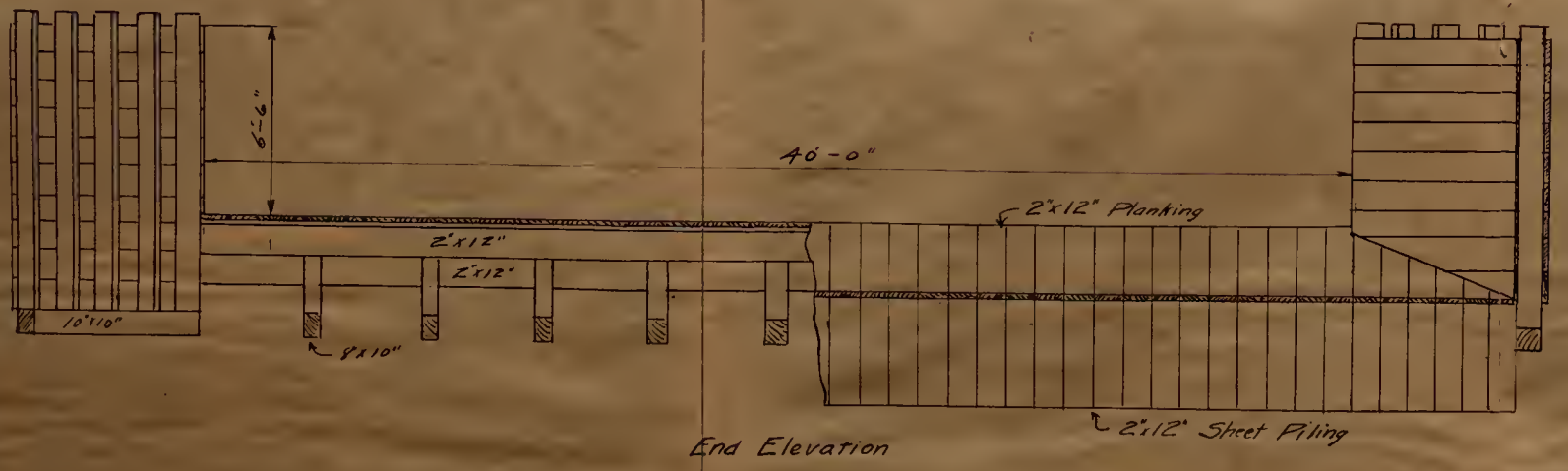
Robert S. Skinner.



Plan



Side Elevation



End Elevation

Scale, 1 inch = 4 feet.

DESIGN
of a
STORAGE RESERVOIR FOR IRRIGATION
Forest Canon Reservoir, Larimer County, Colorado.
Details of Flumes.

University of Illinois

June 1907

Robert S. Larimer.